



LT Structure Function in Pion Electroproduction

Jlab HallC 2006 user meeting

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Experiment introduction

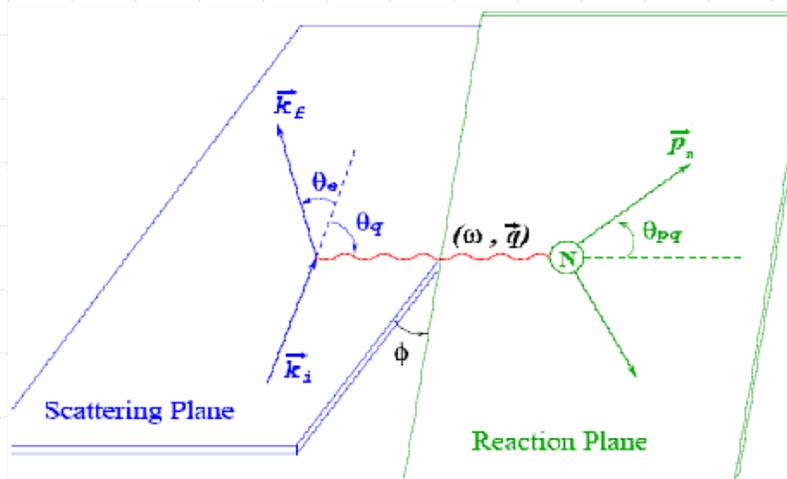
◆ Duality in Meson Electroproduction (E00-108)

- August 2003
- Beam energy 5.496 GeV
- $H(e, e' \pi^\pm)X$, $D(e, e' \pi^\pm)X$, $Al(e, e' \pi^\pm)X$
- HMS -- π^\pm
SOS -- e'
- Three sets of measurements
 - ◆ z-scan ($Z=0.37-0.97$) at fixed $x_{Bj}=0.32$
 - ◆ x-scan ($x_{Bj}=0.26-0.60$) at fixed $Z=0.55$
 - ◆ Pt-scan (θ_{pq} -scan) at fixed $Z=0.55$ and $x_{Bj}=0.32$

$z=E_\pi/\nu$ the fraction of the virtual photon energy carried by meson
 $x_{Bj}=Q^2/2M_p \nu$ the fraction of nucleon momentum carried by struck quark
 $p_T=p_\pi \sin \theta_{pq}$ the transverse momentum of pion

Experiment introduction

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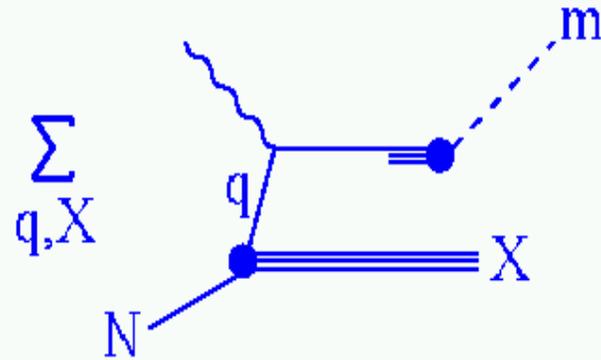
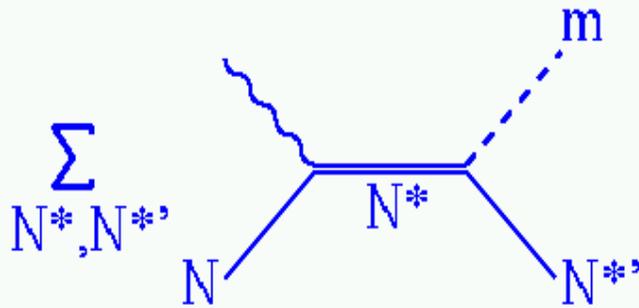
Kinematics for $N(e, e' \pi)$ Reaction

- ϕ the angle between the electron scattering plane and reaction plane containing virtual photon and pion
- θ_{pq} the angle between virtual photon and pion

Experiment introduction

hadronic description

quark-gluon description



$$\sum_{N'^*} \left| \sum_{N^*} F_{\gamma^* N \rightarrow N^*}(Q^2, W^2) \mathcal{D}_{N^* \rightarrow N'^* M}(W^2, W'^2) \right|^2$$

$$\sum_q e_q^2 q(x) D_{q \rightarrow M}(z)$$

Transition

Decay

Quark

Fragmentation

Form Factor

Amplitude

Distribution

Function



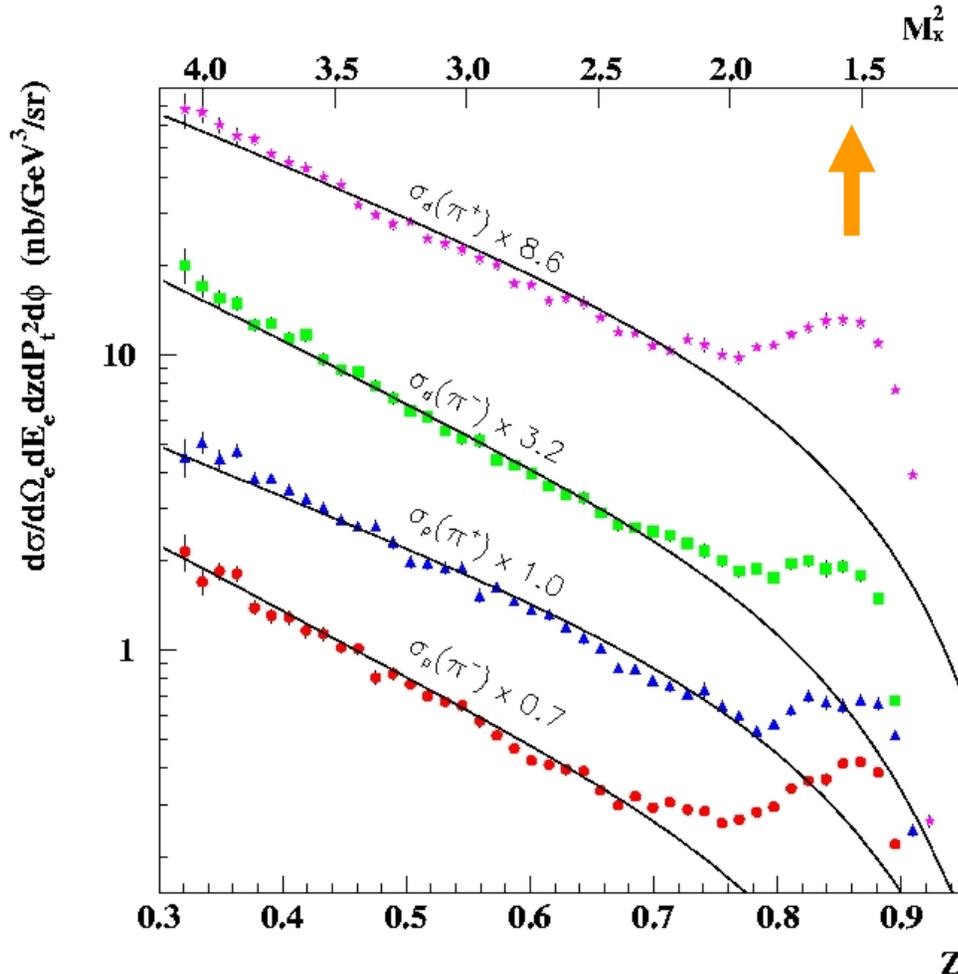
Monte Carlo (SIMC)

Conventionally the meson yield dN/dz arises in terms of a fit (with parameters b , A and B) to the cross section, with normalization provided by the corresponding inclusive cross section:

$$\frac{\frac{d\sigma}{d\Omega_e dE_e dx dp_\perp^2 d\phi}}{\frac{d\sigma}{d\Omega_e dE_e}} = \frac{dN}{dz} b \exp(-bp_\perp^2) \frac{1 + A \cos(\phi) + B \cos(2\phi)}{2\pi}$$

- **No ϕ dependence**
- π^\pm yield N^{π^\pm} factorized into quark density distributions $q_i(x)$ and fragmentation functions $D_{q_i}^{\pi^\pm}$
$$N^{\pi^\pm} = \sum_q e_q^2 q(x) D_{q \rightarrow M}(z)$$
- CTEQ5M parton distribution functions
- fragmentation function $D_u^{\pi^+} + D_u^{\pi^-} = D_d^{\pi^-} + D_d^{\pi^+} = D^+ + D^-$
- to separately give D^+ and D^- , we use the ratio of D^-/D^+ from HERMES data
- $b=4.37$, close to final value

Experiment data vs. SIMC



Dashed curves: SIMC

$$\sum e_q^2 q(x) D_{q \rightarrow M}(z)$$

Surprising similarity
between low-energy
factorization ansatz
and JLab $^1\text{H}(e, e' \pi^+)X$,
 $^1\text{H}(e, e' \pi^-)X$, $^2\text{H}(e, e' \pi^+)X$,
and $^2\text{H}(e, e' \pi^-)X$ data.



Formula

The differential cross section for single pion electroproduction in the one photon exchange approximation can be written as

$$\frac{q_E, q_U^{\circ} q_U^{\mu}}{q_Q} = L \frac{q_U^{\mu}}{q_Q} \quad \text{where} \quad L = \frac{J_{\mu} E}{\alpha E_i M_{\gamma} - W_{\gamma}} \frac{J - \epsilon}{J}$$

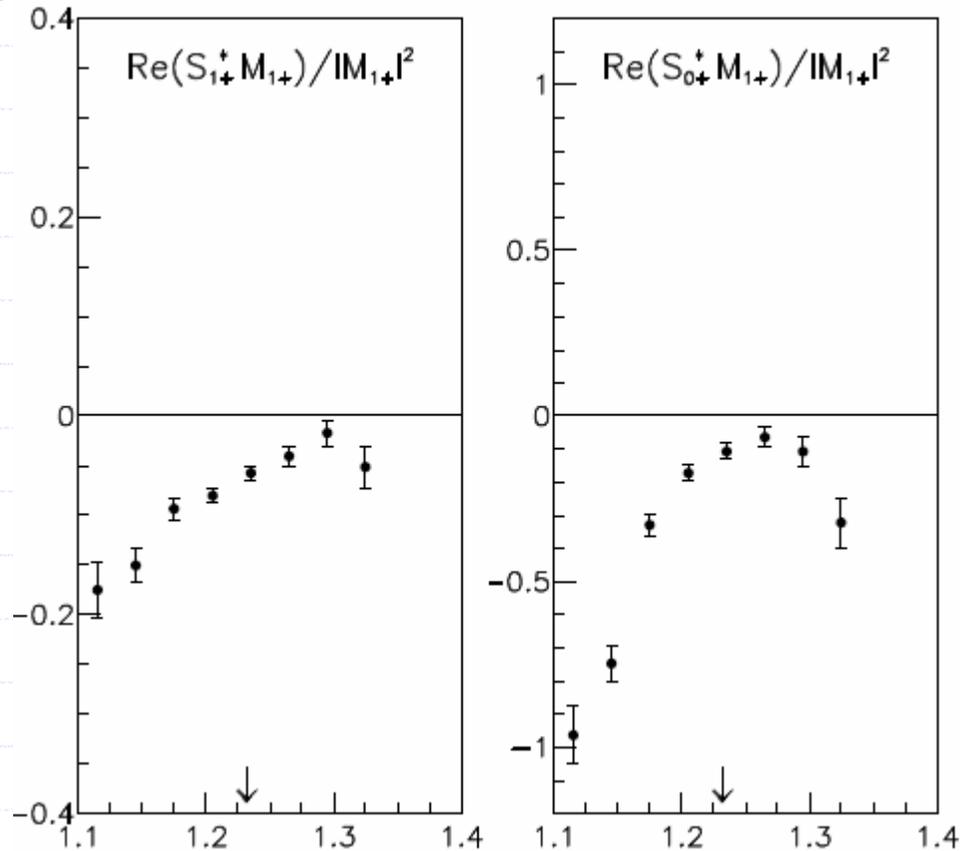
$$\frac{q_U^{\mu}}{q_Q} = Q^{\perp} + \epsilon Q^{\Gamma} + \epsilon Q^{\perp\perp} \cos \gamma \phi + \sqrt{\epsilon(J + \epsilon)} \sqrt{J} Q^{\Gamma\perp} \cos \phi$$

$$\frac{\frac{d\sigma}{d\Omega_e dE_e dx dp_{\perp}^2 d\phi}}{\frac{d\sigma}{d\Omega_e dE_e}} = \frac{dN}{dz} b \exp(-bp_{\perp}^2) \frac{1 + A \cos(\phi) + B \cos(2\phi)}{2\pi}$$

$$A \sim \sigma_{LT}, \quad B \sim \sigma_{TT}$$



ϕ Dependence of Δ Resonance



Results from Frolov thesis show peaks around Δ resonance

Δ resonance has strong ϕ dependence



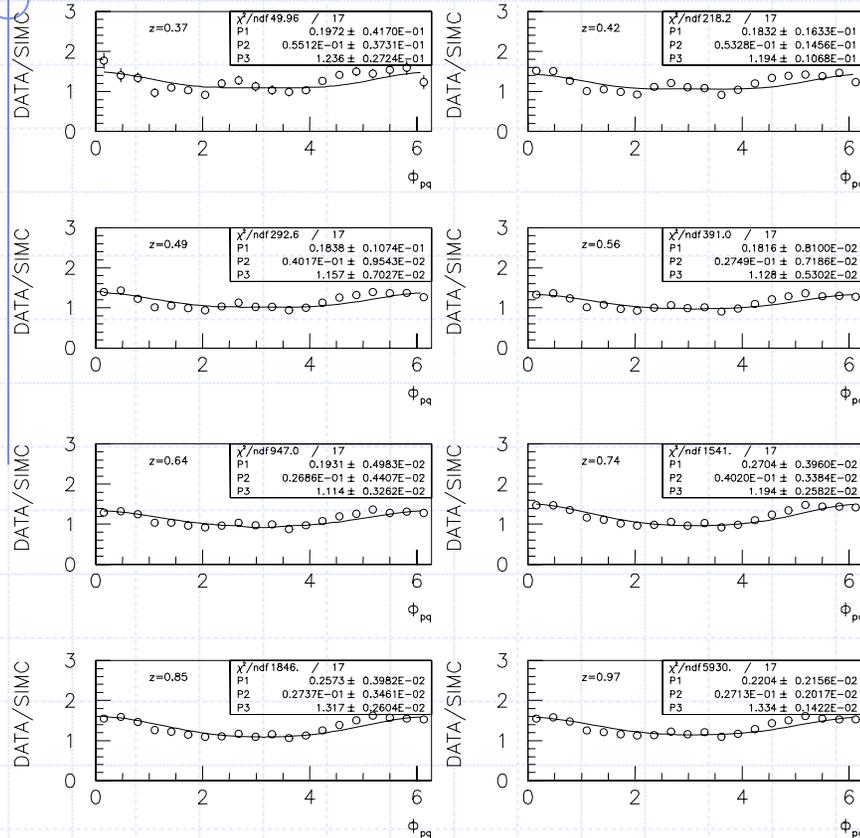
A, B values

Using pion normalized yield from experimental DATA and SIMC to get the ϕ dependence of pion cross section

$$f(\phi) = p3 + p1 \cdot \cos \phi + p2 \cdot \cos 2\phi$$

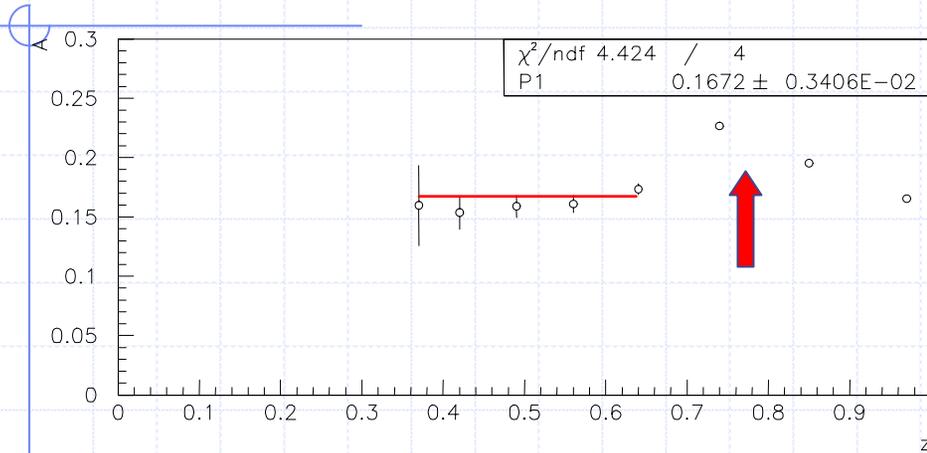
$$A = p1 / p3 \propto \sigma_{LT}$$

$$B = p2 / p3 \propto \sigma_{TT}$$

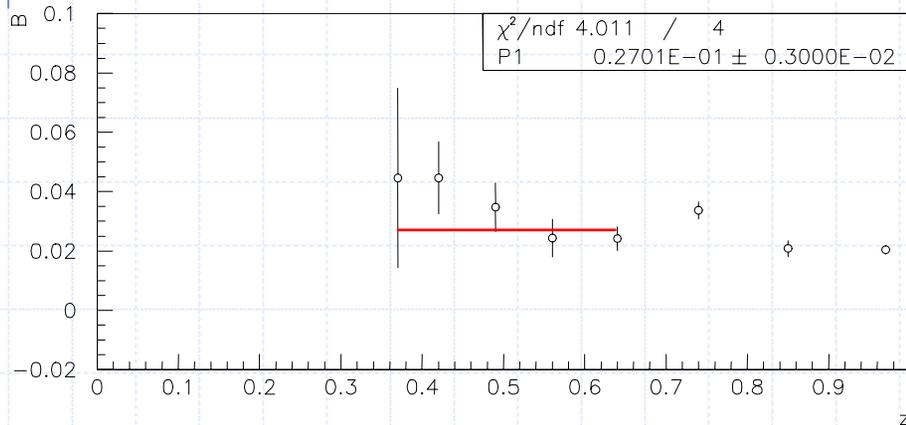


example fitting plots of π^+ from LD₂ for 8 z settings

A, B values



- ◆ A, B values change along z
- ◆ Both have a peak ~ z=0.8
- ◆ A, B values of π⁺, π⁻ from LD₂ and LH₂, all have similar shape.

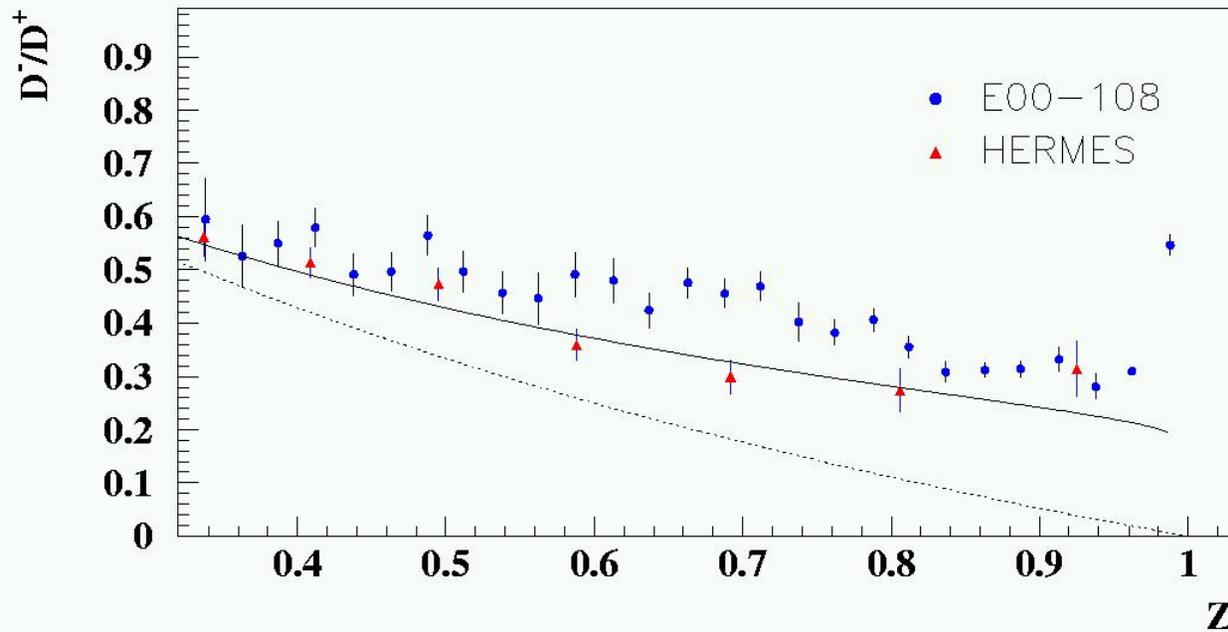


A, B values (LD₂, π⁺)

D⁻/D⁺

From deuterium data:

$$D^-/D^+ = (4 - N_{\pi^+}/N_{\pi^-}) / (4N_{\pi^+}/N_{\pi^-} - 1)$$





D⁻/D⁺

From deuterium data:

$$D^-/D^+ = \frac{(4 - N_{\pi^+}/N_{\pi^-})}{(4N_{\pi^+}/N_{\pi^-} - 1)}$$

F. Close et al : SU(6) Quark Model

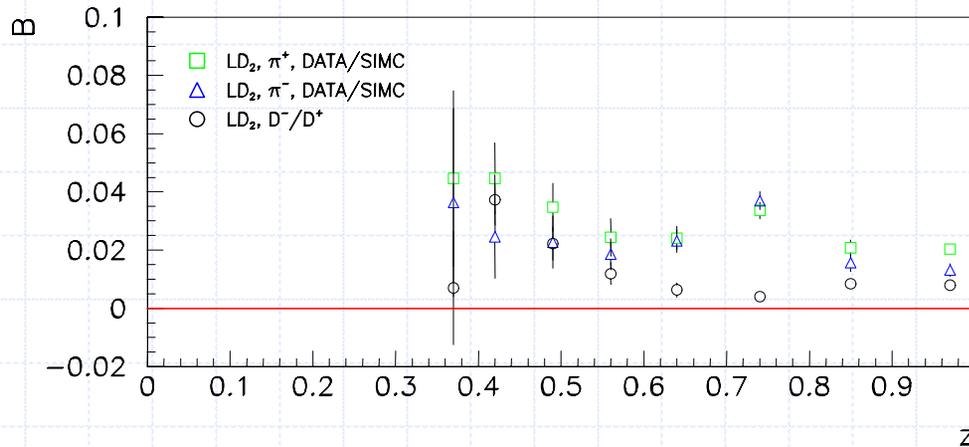
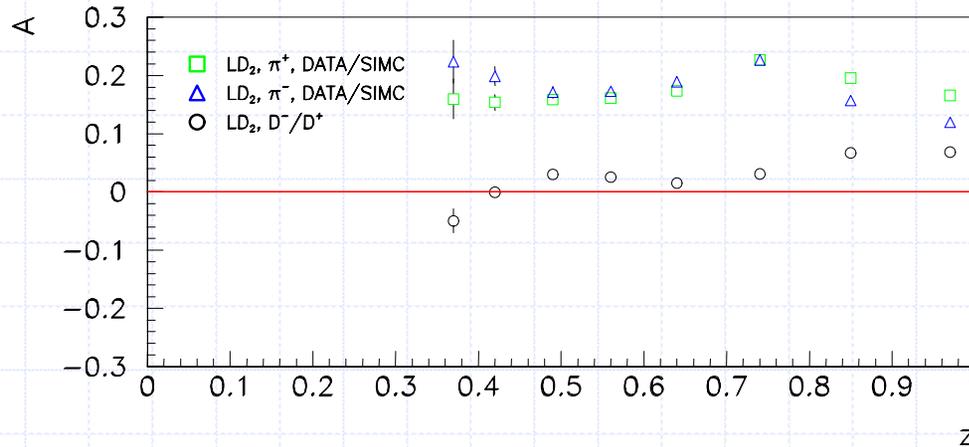
Production rates in various channels in semi-inclusive pion production at resonance region.

SU(6) and *SU(3) × SU(2)* Multiplet Contributions to π^\pm Photoproduction

W'	$p(\gamma, \pi^+)W'$	$p(\gamma, \pi^-)W'$	$n(\gamma, \pi^+)W'$	$n(\gamma, \pi^-)W'$
56;8	100	0	0	25
56;10	32	24	96	8
70; ² 8	64	0	0	16
70; ⁴ 8	16	0	0	4
70; ² 10	4	3	12	1
Total	216	27	108	54



A, B values



While pion electroproduction cross section has apparently ϕ dependence, the ratio D⁻/D⁺ mainly cancels out this effect.



More Formula

The differential cross section of single pion production can be written in another form:

$$\frac{q_0^4}{q_0} = a + \varepsilon \cdot p + \varepsilon \cdot c \cdot \sin^2 \theta \cos 2\phi + \sqrt{5\varepsilon(1+\varepsilon)} \cdot b \cdot \sin \theta \cos \phi$$

$$c = c_0 \quad d = d_0 + d_1 \cos \theta \approx d'_0 \quad (\text{small } \theta)$$

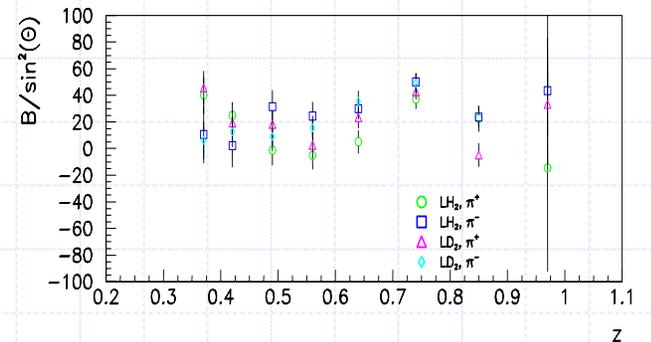
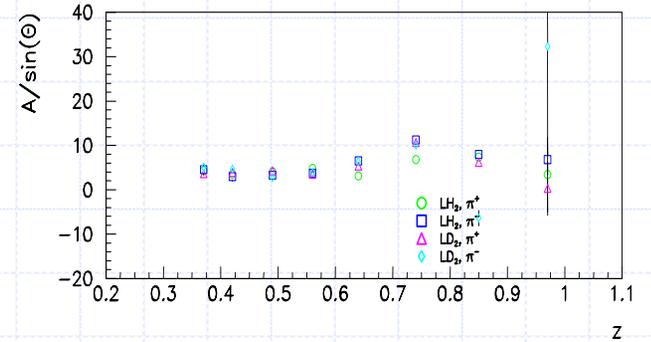
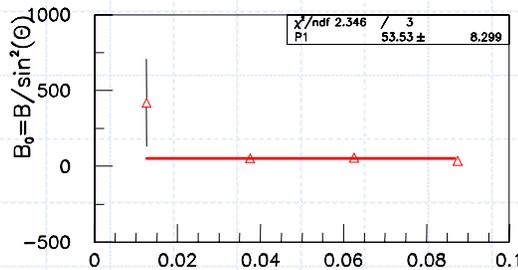
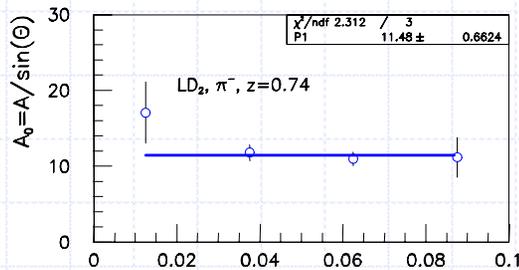
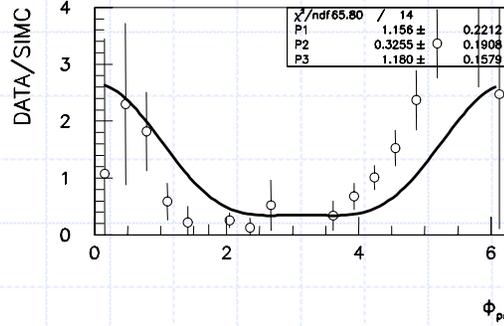
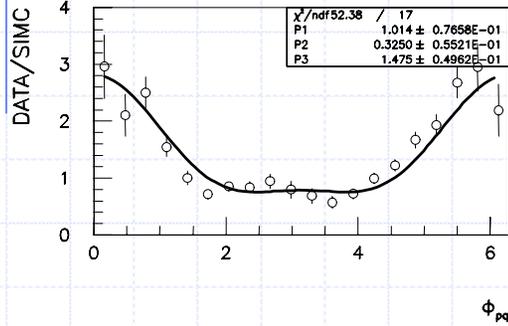
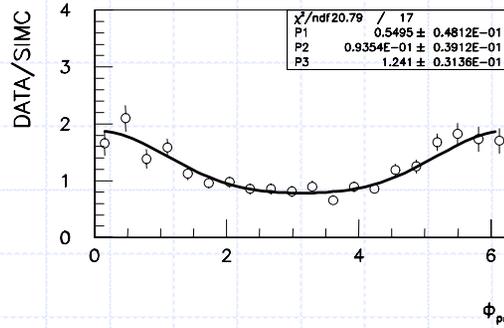
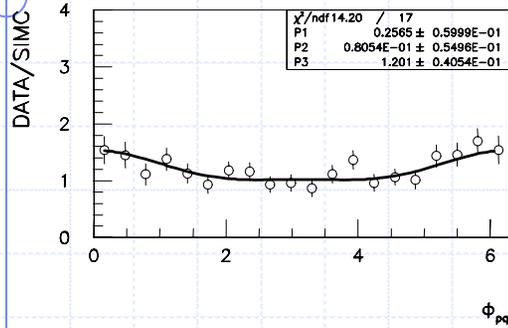
$$\frac{\frac{d\sigma}{d\Omega_e dE_e dx dp_\perp^2 d\phi}}{\frac{d\sigma}{d\Omega_e dE_e}} = \frac{dN}{dz} b \exp(-bp_\perp^2) \frac{1 + A \cos(\phi) + B \cos(2\phi)}{2\pi}$$

$$A = A_0 \sin \theta \sim d'_0 \sin \theta$$

$$B = B_0 \sin^2 \theta \sim c_0 \sin^2 \theta$$



A_0, B_0 values



$LD_2, \pi^+, z=0.75$



conclusion

- ◆ The pion cross section from semi-inclusive electroproduction has ϕ dependence, and the $\cos \phi$ term (LT structure function, σ_{LT}) dominates.
- ◆ σ_{LT} raises $z \sim 0.8$ (Δ resonance).
- ◆ Ratio D^-/D^+ mainly cancels out ϕ dependence.
- ◆ Using extra information from θ , constant A_0 , was found at resonance region, which is consistent with theory.
- ◆ More effort is needed to improving the analysis and calculations from quark model.